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Mössbauer Studies on Supersaturated FeSb Solid Solutions

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The hyperfine field at iron sites in supersaturated FeSb solid solution was determined by Mössbauer effect. The mean hyperfine field $\bar{H}$ decreases with increasing Sb content at a rate of $d\bar{H}/dc = -101$ kOe. The maximum hyperfine field seems to be concentration dependent. The obtained values of H_{max} are 333 kOe for 4 at%Sb and 355 kOe for 17 at%Sb. The obtained values of $d\bar{H}/dc$ and H_{max} in our measurement are qualitatively in agreement with those obtained by Vincze and Aldred for dilute FeSb solid solution.

KEY WORDS: Magnetic hyperfine field / Bcc alloy /

INTRODUCTION

The Mössbauer study on α-Fe solid solutions with non-transition atoms is of interest in understanding the influence of surrounding solute atoms on the local changes of magnetic hyperfine field. From this point of view, many investigations have been studied for several alloy systems.[1~5] The Mössbauer spectra were satisfactorily accounted for with assuming the random distribution of solute atoms and impurity effect being localized. Namely the magnetic hyperfine field of Fe atom depends on the number of solute atoms only at the first and the second nearest neighbor sites.

According to Vincze and Aldred,[5] Al and Si, and Ga, Ge, As, Sn and Sb seem to belong to different groups with regard to the concentration dependence on the hyperfine field H_0 corresponding to the site without impurity neighbors, and the concentration dependence of bulk magnetization $d\mu/dc$. In the case of FeSb alloy system, no information was obtained on the local changes of magnetic hyperfine field at ^{57}Fe nuclei which are surrounded by many Sb atoms, because of the limitation of the equilibrium solid solubility of Sb in α-Fe ($\sim$4 at%) at room temperature.[6] We produced metastable FeSb alloy films by simultaneous vapor depositions of Fe and Sb onto acetylcellulose sheets maintained at room temperature, and obtained supersaturated bcc Fe solid solutions with 0$\sim$29 at%Sb[7]. In the present paper, we report the study of magnetic hyperfine field at ^{57}Fe nuclei in supersaturated bcc FeSb alloys by Mössbauer effect.

EXPERIMENTAL

Bcc FeSb alloy films were produced by simultaneous vapor depositions of Fe and Sb onto acetylcellulose sheets maintained at room temperature as was described

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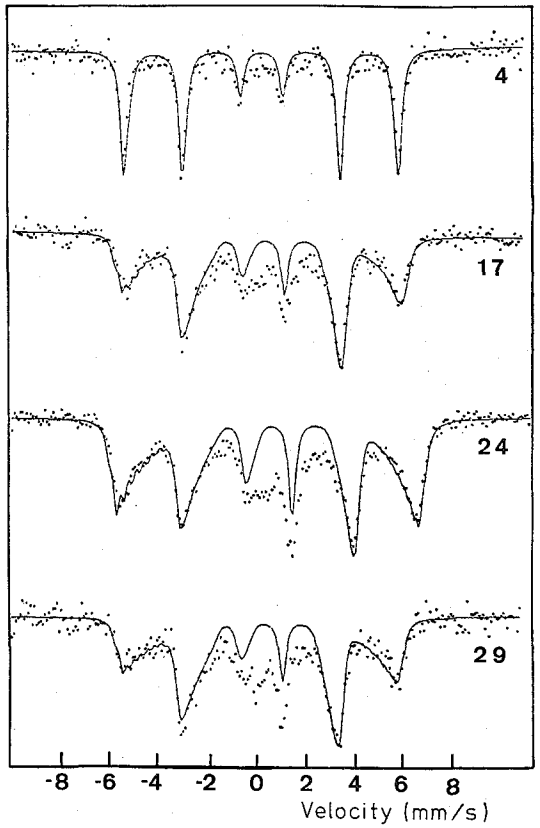

Fig. 1. Fitted (solid line) and experimental spectra from 4 to 29 at%Sb at 295 K.

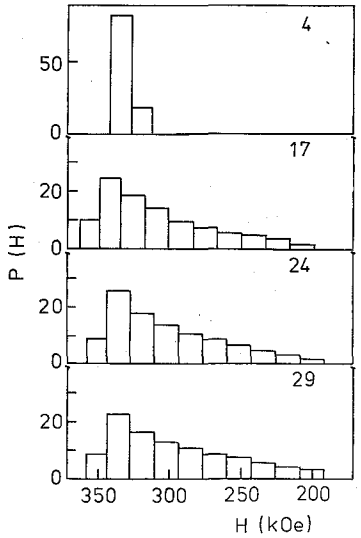

Fig. 2. Hystograms of the probability of hyperfine fields giving the fitted curves in Fig. 1.

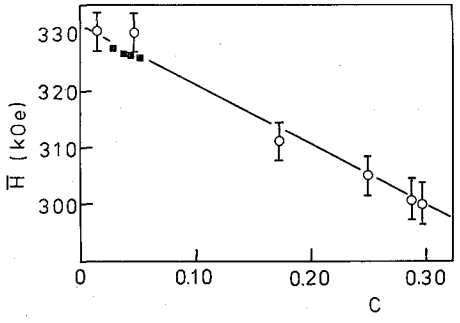

Fig. 3. Dependence of mean hyperfine field $\bar{H}$ on Sb content at 295 K.
○; present experiment, ■; Vincze and Aldred.[5]

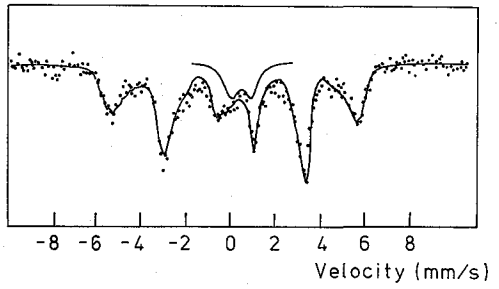

Fig. 4. Fitted spectra including a paramagnetic doublet (oxide phase with I.S.=0.32 mm/s and ΔE=1.0 mm/s) of 17 at%Sb at 295 K.

in the previous paper.[7] Mössbauer effect measurements were made at 295 K using a conventional spectrometer. ^{57}Co embedded in copper matrix was used as a source. The velocity scale was calibrated by using an iron foil as the standard absorber.

The typical Mössbauer spectra taken at 295 K are shown in Fig. 1. On each spectrum we have performed a fitting by a superposition of several steps of the six Lorentzians with different Zeeman splittings ranging from the maximum hyperfine field H_{max} in the steps of 15 kOe. In addition the followings were assumed: (a) the isomer shift varies slightly. It is 0.00 mm/s at H_{max} and increases with Δi mm/s for each step, (b) there is no quadrupole effect, (c) the line width is 0.32 mm/s. The resulting P(H) curves are shown in Fig. 2. The fitted curves are shown as the full line in Fig. 1. In this case we used Δi=0.032 mm/s. The mean hyperfine fields $\overline{H}(c)$ obtained by this fitting are present in Fig. 3. In some spectra, a quadrupole splitting paramagnetic doublet due to oxide phase was superposed on the magnetic hyperfine spectrum. The typical fitting curve including the oxide phase is shown in Fig. 4. In this spectrum the portion of the oxide phase was 17% and the observed Mössbauer parameters are I.S.=0.32 mm/s and ΔE=1.00 mm/s. This oxide phase shows hyperfine spectrum at 4.2 K with $\overline{H}$=480 kOe. Analysis on the results at 4.2 K was not attempted since the reduction of oxide fraction is actually unreliable.

DISCUSSION

The field H_{max} is found to be concentration dependent. The obtained values of H_{max} are 333 kOe for 4 at%Sb, 355 kOe for 17 at%Sb and 350 kOe for 24 and 29 at%Sb. The similar behavior was observed by Vincze and Aldred[5] for dilute bcc FeSb solid solution. In their case, they fitted the spectra by the assumptions that only the first and second neighbor effects are resolvable in the Mössbauer spectra and the multiple impurity neighbor effects are additive. The hyperfine field at iron atoms with no neighbor impurities, H_0 depends slightly on the concentration. The value of H_0 increases from 331 kOe for 2.4 at%Sb to 333 kOe for 4.4 at%Sb. The value H_{max} may correspond to H_0 for the cases of 4 and 17 at%Sb. While, H_{max} does not correspond to H_0 for the cases of 24 and 29 at%Sb, because the probability of occurrence for a configuration with no neighbor impurities is quite small. H_{max} for the cases of 24 and 29 at%Sb probably corresponds to the hyperfine field at iron atoms with one neighbor impurity. The obtained values of H_{max} in our measurement are closely connected to those obtained by Vincze and Aldred for dilute FeSb solid solution. The hyperfine field at iron atoms with no neighbor Sb atom increases with increasing Sb content.

The value of $\overline{H}$ decreases linearly with increasing composition c at a rate of $d\overline{H}/dc=-101$ kOe. Vincze and Aldred[5] obtained the value of $d\overline{H}/dc$ which changes with composition from -130 kOe for 2.4 at%Sb to -105 kOe for 4.4 at%Sb.

It was found for FeAl alloys that H_0 is constant and $\overline{H}$ decreases with increasing Al content at a rate of $d\overline{H}/dc=-200$ kOe.[6] Al impurity atoms act more or less like non-magnetic holes in the bcc Fe. In contrast, an increase was found in the magnetic moments of Fe with dissolving Sb. To use the value of H_{max} and the proportionality assumed 2.22 μ_B=330 kOe, we can estimate the magnetic moment of

Fe atoms which have no neighbor Sb impurities. It is 2.51 μ_B for 17 at% Sb. Similar behavior was observed in FeGa,[4] FeGe,[5] and FeSn[5] solid solutions. The atomic radii of Sb, Ga, Ge, and Sn are larger than that of Fe and the lattice parameter of bcc Fe solid solutions with those solute atoms increases with increasing composition.[8] This leads to the expansion of metal-metal distance in the bcc matrix. As is well known, the exchange integral J depends on the atomic distance (Bethe curve). The value of J increases when the atomic distance of bcc Fe is expanded. This may lead to the increase of magnetic moment of Fe atoms with no neighbor Sb in FeSb solid solution.

REFERENCES

(1) G. K. Wertheim, V. Jaccarino, J. H. Wernick, and D. N. E. Buchanan, *Phys. Rev. Lett.*, **12**, 24 (1964).
(2) P. A. Flinn and S. L. Ruby, *Phys. Rev.*, **124**, 34 (1961).
(3) M. B. Stearns, *Phys. Rev.*, **147**, 439 (1966).
(4) L. R. Newkirk and C. C. Tsuei, *Phys. Rev.*, **B4**, 4046 (1971).
(5) I. Vincze and A. T. Aldred, *Phys. Rev.*, **B9**, 3845 (1974).
(6) M. Hansen, "Constitution of Binary Alloys," 2nd ed, McGraw-Hill, New York, 1958, p. 708.
(7) T. Shigematsu, T. Shinjo, Y. Bando, and T. Takada, *Bull. Inst. Chem. Res., Kyoto Univ.*, **57**, 310 (1979).
(8) W. B. Pearson, "A Handbook of Lattice Spacings and Structures of Metals and Alloys," Vol. 1, Pergamon Press, New York, 1958.